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**JOHN F. KENNEDY SPACE CENTER
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SHUTTLE SYSTEMS 3-D APPLICATIONS

Application of 3-D Graphics in Engineering Training for Shuttle Ground Processing

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ABSTRACT

This project illustrates an animation of the orbiter mate to the external tank, an animation of the OMS POD installation to the orbiter, and a simulation of the landing gear mechanism at the Kennedy Space Center. A detailed storyboard was created to reflect each animation or simulation. Solid models were collected and translated into Pro/Engineer's prt and asm formats. These solid models included computer files of the: orbiter, external tank, solid rocket booster, mobile launch platform, transporter, vehicle assembly building, OMS POD fixture, and landing gear. A depository of the above solid models was established. These solid models were translated into several formats. This depository contained the following files: stl for stereolithography, stp for neutral file work, shrinkwrap for compression, tiff for photoshop work, jpeg for Internet use, and prt and asm for Pro/Engineer use. Solid models were created of the material handling sling, bay 3 platforms, and orbiter contact points. Animations were developed using mechanisms to reflect each storyboard. Every effort was made to build all models technically correct for engineering use. The result was an animated routine that could be used by NASA for training material handlers and uncovering engineering safety issues.

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1. INTRODUCTION

The following assignments reflect application of 3-D models to the education of Kennedy Space Center workers. These assignments include: Orbiter Mate to the External Tank (S0004), OMS Pod Installation to Orbiter (V5011.1 & 2), and Landing Gear Operation (Graphics to Kinetic). An animated simulation of each assignment was to be created. Pro/Engineer's mechanisms module was to be used to kinetically control motion or degrees of freedom.

2. ASSIGNMENTS

The initial project was to develop and animate the Orbiter Mate to the External Tank. To accomplish this duty, several tasks had to be completed. These tasks included: collecting 3-D models, drawing 3-D models, translating 3-D models into a common language, securing engineering drawings, collecting operational manual documents, and using motion simulation techniques. Compression techniques were incorporated to handle large file sizes. The animation of assembly routines required an analysis that was accomplished by development of a detailed storyboard. Storyboard routines were refined to reflect operational procedure. The scope of the problem grew to include the creation of a Model Depository, animation of OMS Pod Installation to the Orbiter, and Orbiter Landing Gear Operation. Stereolithographic techniques were used to create scaled models. The result of this project will be a set of training aids for the education of Kennedy Space Center workers. A secondary benefit will be the creation of a 3-D solid model depository that engineers may use in their design and analysis activities.

3. STATUS OF ASSIGNMENTS

The status of the Orbiter Mate to the External Tank (S0004) follows. This project is approximately 50% complete. Sling parts have been drawn, A storyboard has been completed, Orbiter/Transporter attach points have been drawn, The bi-pod, salad bowl, platforms for bay 3, and crane hook need to be drawn. There is a need for a better orbiter model. Assembly Models will have to be created to include combinations of the following: transporter, orbiter, and contact points; orbiter, sling, and crane; and orbiter, external tank, sling, SRB, and MLP. Each of the assembly models will be confined within platforms of Bay 3 and/or the VAB. Figure 1 shows a South View of VAB and Figure 2 shows the Forward Spreader Beam Model. See Figure 1 and Figure 2.

South View of VAB Model

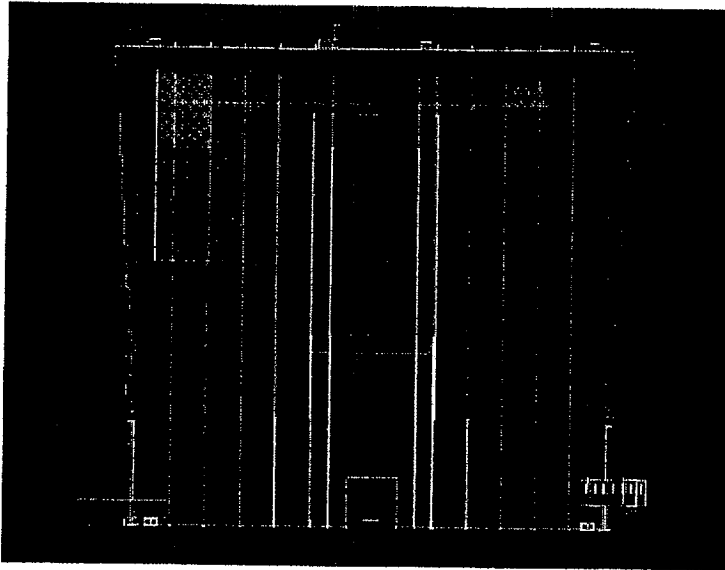


Figure 1: SOUTH VIEW OF VAB MODEL

Forward Spreader Beam Model

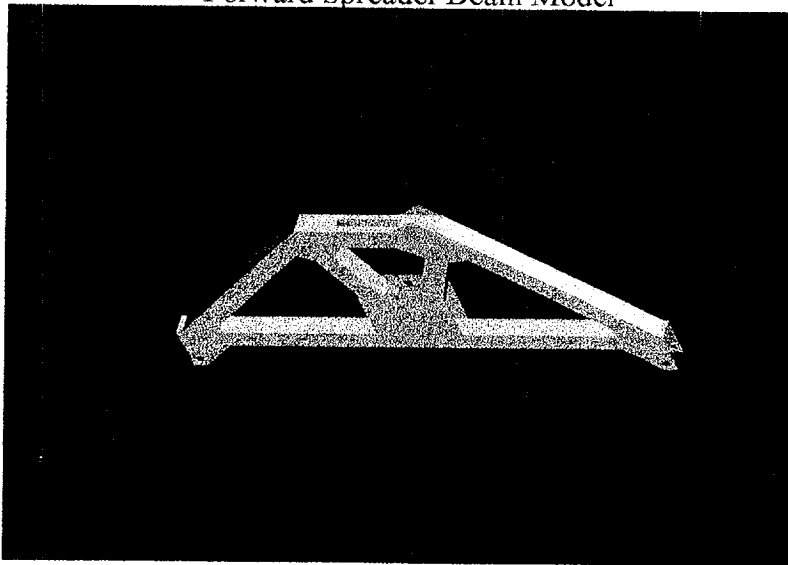


Figure 2: FORWARD SPREADER BEAM MODEL

The status of the OMS Pod Installation to Orbiter (V5011.001 & 2) follows. This project is 10%

complete. OHM's pod fixtures have been drawn. The storyboard is incomplete. The OPF model, OPF assembly platforms, and orbiter model sub assemblies need to be drawn. A better orbiter model needs to be drawn. Assembly models of the orbiter, OHM's POD fixtures, and OHM's POD will have to be created. Each of the assembly models will be confined within the OPF.

The status of the Landing Gear Operation (Graphics to Kinetic) follows. This project is 30% complete. The landing gear parts have been drawn. A storyboard needs to be created. Some parts have been modeled using sterolithography techniques. The cam displacement charts and wheel well need to be drawn. Movements have to be analyzed. Each of the assembly models will be confined within the left wing of the orbiter.

4. 3-D MODEL FILE DEPOSITORY

A 3-D Model File Depository is available for engineering use. 3-D models were collected in the following formats: (CATIA, CADAM, Intergraph, Pro/Engineer, etc.) Files were translated into a single model format (Pro/Engineer .prt & .asm). Information was translated into a manner that can be used by NASA employees. Models were translated into formats that may be used for multiple purposes (shrinkwrap, STEP, stl, TIFF, JPEG, etc).

The 3-D Model File Depository contains the following files. See Table 1.

File Format	Type	Number
.prt	Pro/E Part	2487
.asm	Pro/E Assembly	555
Shrinkwrap	Pro/E Compressed	40
Step (.stp)	Neutral File	37
.stl	Sterolithography	37
JPEG (.jpg)	Internet	41
TIFF (.tif)	Photo Shop	34

Table 1: 3-D MODEL FILE DEPOSITORY TYPES

The initial approach was to obtain all solid models required to complete animations. Solid models of the vehicle assembly building, mobile launch platform, transporter, orbiter, external tank, solid rocket boosters, OHMS POD fixture, landing gear, and bay 3 platforms were collected. Many solid models were missing. These were mainly of the material handling sling, and orbiter attach points. All files were translated into stl, stp, shrinkwrap, jpeg, and tiff formats. This provides a tessellation file for sterolithography, a neutral file that other programs could read, a compressed solid model file for handling large file size, an internet picture file, and a print shop picture file. This resulted in a model depository that engineers could use in making analytical decisions. This model depository is almost complete and is available for NASA engineers to use.

Table 2 details the sub-directories created as part of the 3-D Model Depository. See Table 2.

Directory:		3-D MODEL DEPOSITORY	
Sub-Directories:	Orbiter ET Mate	OMS POD Install	Orbiter Landing Gear
Sub-Directories:	ET Bipod Aft connect High bay 3 MLP SRB hdp Rainbird Orbiter ET SRB Orbiter Sling SRB Transporter VAB Integrated S0004	OMS2 OMS Handling SSV Elements Integrated OMS	Door retract mechanism MLG clean MLG Up-lock mechanism OV 102-052103 OV102 left wing OV102 MADS stick OV107 Wing Feb Up-stop assembly Integrated V5011

Table 2: 3-D MODEL FILE DEPOSITORY SUBDIRECTORIES

Pro/Engineer Wildfire has proven to be a top choice for data exchange input and output data exchange. Using Wildfire data exchange is quite possible between Catia, Unigraphics, Solidworks, and AutoCAD [1]. These data exchanges may be made using STEP, IGES, ACIS, Parasolid, STL, VRML, and DXF. Wildfire will import STL, VRML, STEP, IGES, faceted, Catia SOLM, CGM, CADAM, Medusa, DXF, and DWG. Export formats include: STEP, SET, IGES, Medusa, CGM, DXF, DWG, ProductView, and Shrinkwrap. Direct translation is possible to Catia, PDGS, CADAM, Medusa, Stheno, AutoCAD, DFX, DWG, Parasolids, and ACIS. Other translations possible are IGES, STEP, SET, VDA, ECAD, CGM, Cosmos/M, Patras, Supertab, SLA, CGM, JPEG, TIFF, Render, VRML, and Inventor. Wildfire data exchange capabilities make it a good software for handling files from many different sources.

Point Clouds are typically a series of points with (x, y, z) coordinates. These points lie on a digitized surface. These points are produced by scanners or digitizers. Point Clouds need to be surface reconstructed. This may be done by meshing which creates a triangular polygonal mesh and a resulting STL file; or by segmentation which corresponds to faces, planes, cylinders, etc, and results in IGES or STEP files. The use of Point Clouds is becoming increasingly popular in re-engineering activity and for adding detail to more primitive features. Point Cloud data should be used to detail primitive solid models.

5. COOPERATIVE ANIMATIONS

There was an effort to initiate a cooperative animation simulation with (Boeing/NASA). The project was to be a joint Boeing/NASA modeling simulation of Orbiter Mate to the External Tank (S0004). DELMIA, a custom built interface, and Ensign were to be used to enact motion and simulate the material handling activities of S0004..

There was an effort to initiate a cooperative Digital Shuttle animation with (USA/NASA). This project was to be a joint USA/NASA modeling animation of Orbiter Mate to the External Tank

(S0004). Alias was to be used to enact motion. Digital imaging techniques were to be incorporated to enhance primitive parts. This project was to be created in VRML format.

6. MECHANISM ANIMATION SIMULATION

Mechanism animation simulation was to be developed using the following methods. They include the Design Animation Option of Pro/Engineer (Image driven), and the Motion Simulation Option of Pro/Mechanica (kinetic driven), Shrinkwrap files were to be used to manage file size. Custom storyboard routines were created to time frame each routine. Mechanisms were to be created. The process includes: configuring joint axis settings, defining drivers and motion, reviewing mechanisms, reviewing motion analysis, optimizing mechanism designs, calculating degrees of freedom, and setting range of motion. The language of mechanisms included terms such as fix, welded, and translate. See Table 3 for a mechanism joint example.

MECHANISM JOINT EXAMPLE	
A.	The VAB is positioned using Fix.
B.	The Orbiter is welded to the transporter.
C.	Move to translate the orbiter and transporter from outside the VAB to the inside of the VAB and in align with Bay #3.

Table 3: MECHANISM JOINT EXAMPLE

Sterolithography is an instant prototyping process. This process produces plastic replicas of an object. The replicas may be produced scaled. Sterolithography lets the designer complete the full design process from initial concept to replica of a product. A Pro/Engineer part file is tessellation file is processed and used to create a M & G code for prototype production. Plastic is placed to build-up the part shape and size description. Wax is used for support. The wax is cleaned from the part by using an ultrasonic cleaning process. The resulting part is quite accurate in dimension.

Assembly modeling involves the combination of a number of parts. Using assembly methods sub-assemblies and final assemblies may be created [2], [3], and [4]. Assembly components are put together using assembly constraints. When a component becomes part of an assembly, it is considered placed [5] and [6]. This means that it is fully constrained. Mate, align, and insert are the main constraint methods. Assembly methods are used in animation.

Pro/Engineer's Design Animation option lets you organize parts and assemblies in an animation [7] and [8]. After routines have been coordinated, the animation may be played back. This module lets you run, create, and manage an animation. When using this option, animation may be created by linking a series of snapshots. A timeline is used to control motion.

It is claimed that motion is a virtual prototyping tool used for mechanism analysis and design [0], [10], and [11]. Motion is a module of Pro/Mechanica. Its use is in the finalization of a design. After a mechanism has been designed, it may be tested using forces. Loads generated may be measured. Use of these mechanisms give engineers an analysis tool.

7. STORYBOARDS

Storyboards were created or are being developed to detail material handling routines for the Orbiter Mate to the External Tank and OMS POD Installation. Another storyboard is being developed for the kinetic movement of the Landing Gear Operation. Each storyboard slide contains three types of information. Appendix B gives an example of a slide. See Appendix B. This slide is titled Attach Sling to Orbiter. It shows an animation of the Attachment of the Left/Right Aft Adapter in the window. The installation is attained by rotating the Inner Hand Wheel Adapter a minimum of 13 turns clockwise. The installation animation may be repeated for training purposes.

8. CONCLUSION

The use of digital imaging must be researched since there is a large amount of 3-D modeling building that must be completed. This use of digital imaging should allow for the quick creation of 3-D models.

Translation between various software platforms appears to be a problem. This is especially true when dealing with older 3-D models. Translation workstations should be identified. There file input and output capabilities should be identified. Procedures for preparing files before output should be adopted. Procedures for correcting input files should be adopted.

There must be an assigned responsibility for maintaining a master model depository. This responsibility includes 3-D creation and revision. This group should have the duty of writing files. Their distribution should be in a read-only format. This read-only format file can then be used by manufacturing for post-processing, engineering for material analysis, or drafting for 2-D drawing creation.

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APPENDIX A

ACRONYMS

ASEE	American Society of Engineering Education
ET	External Tank
KSC	Kennedy Space Center
MADS	
MLB	
MLG	
MLP	Mobile Launch Platform
NASA	National Aeronautics and Space Administration
OHM	
OMS	Orbital Maneuvering System
OPF	
OV	
POD	
SRB	Solid Rocket Booster
SSV	
USA	United Space Alliance
VAB	Vehicle Assembly Building

Attach Sling to Orbiter

Attach Left/Right Aft Adapter

- Installation is attained by rotating the Inner Hand Wheel Adapter a minimum of 13 turns CW.

